



## *In vitro* study of the insertion and disinsertion effect on retention of two attachment systems of an overdenture on two implants

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### Abstract

**Objective:** Implant-supported overdentures are a valid treatment option for edentulous patients. The use of two mandibular implants is considered the minimum standard of care. This study evaluated the retentive force of two attachments and their respective connection systems in a mandibular implant-supported overdenture.

**Methods:** Two acrylic blocks were prepared: two parallel implants set 22 mm apart were embedded in one of the blocks, while in the other were positioned the female systems for each attachment system tested (Dalbo Ball BTI<sup>®</sup> and Locator<sup>®</sup> with female components in both clear and pink nylon). A specific machine was designed to measure the retentive force of the attachments over the cycles applied. The speed of insertion/disinsertion was 0.5 Hz, applied constantly.

**Results:** The clear nylon Locator<sup>®</sup> attachments registered the highest initial retention value (85.7 N), followed by the Dalbo-Ball<sup>®</sup> system (62.1 N) and pink nylon Locator<sup>®</sup> (49.6 N). After 5400 cycles, the mean force exerted was highest in the clear nylon Locator<sup>®</sup> attachments (42.3 N) followed by Dalbo-Ball<sup>®</sup> (34.3 N) and pink nylon Locator<sup>®</sup> (24.6 N).

**Conclusion:** The initial retention force decreases over time for the attachment systems tested.

**Keywords:** Dental prosthesis; implant-supported overdentures; attachment system

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### Estudo *in vitro* do efeito de inserção e desinserção na retenção de dois sistemas de *attachments* numa sobredentadura sobre dois implantes

#### Resumo

**Objetivo:** As sobredentaduras sobre implantes são uma opção válida de tratamento para os desdentados totais. A utilização de dois implantes mandibulares é considerada o *minimum standart of care*. Este estudo avaliou a força de retenção de dois sistemas de *attachments* e seus respectivos sistemas de conexão numa sobredentadura mandibular retida por dois implantes.

**Métodos:** Foram confeccionados dois blocos de acrílico: num dos blocos incorporaram-se dois implantes paralelos distanciados de 22 mm; no outro foram instalados os respectivos sistemas fêmea para cada sistema de *attachment* testado (Bola-Dalbo BTI<sup>®</sup> e Locator<sup>®</sup>, com fêmeas em nylon transparentes e cor-de-rosa). Desenvolveu-se uma máquina específica para avaliar a retenção dos *attachments* ao longo dos ciclos aplicados. A velocidade de inserção/desinserção foi de 0,5 Hz, aplicada de forma constante.

**Resultados:** Os Locator<sup>®</sup> com nylon transparente foram os que apresentaram maior retenção inicial (85,7 N), seguidos do sistema de Bola-Dalbo<sup>®</sup> (62,1 N) e dos Locator<sup>®</sup> com nylon cor-de-rosa (49,6 N). Ao fim de 5400 ciclos, a força média exercida foi mais elevada para os Locator<sup>®</sup> com nylon transparente (42,3 N) seguido do sistema de Bola-Dalbo<sup>®</sup> (34,3 N) e, por último, dos Locator<sup>®</sup> com nylon cor-de-rosa (24,6 N).

**Conclusão:** A força de retenção inicial diminui ao longo do tempo para os sistemas de *attachments* testados.

**Palavras-chave:** Prótese dentária; sobredentadura sobre implantes; sistema de *attachment*

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## Introduction

Improvements in the socio-economic conditions and general health of people living in developed countries have led to a progressively aging population. Currently, although teeth are lost later, the longevity of the population has meant an increase in the number of prosthetic oral rehabilitation procedures, including full dentures [1].

Bone reabsorption, subsequent to tooth loss, decreases retention and stability of dentures by changing their biomechanical behavior. These considerations are more significant in the edentulous mandible, where bone reabsorption and muscle dynamics act with greater intensity [2]. Many studies have demonstrated that conventional mandibular dentures are not able to properly restore masticatory function, or improve satisfactorily the quality of life of most patients [3]. There is strong evidence that retention given by the implants used in overdentures is a very important factor for patient satisfaction [4,5].

One of the treatment options recommended is the use of two implants to support and retain the overdenture [6]. Since it offers a simpler and more cost effective solution than implant-supported fixed prosthesis, the use of two implants has been considered by some authors as the standard of care for edentulous patients [7,8].

The use of attachments as a retentive means for overdentures was originally described in Switzerland around 1898, their use being popularized in the 60s by Gilmore [9]. There are various attachment systems proposed for overdenture treatment, including bar systems, ball systems, magnetics and Locator [7]. The location of the implant, the degree of adaptation of the denture base to the edentulous alveolar ridge and the correct use of the attachment system all affect prosthetic retention [4,10].

The retention and longevity of attachments are issues frequently discussed in clinical and in vitro studies. However, there are no criteria for the designation of specific attachment systems for different clinical situations, this choice being left to the discretion of the professional [11]. Different studies indicate that attachment systems suffer wear in their retentive mechanism over time [12,13]. The masticatory function associated with the successive insertion and disinsertion of a prosthesis, the incidence of horizontal, vertical and tangential forces, and the possible coexistence of parafunctional habits are variables that may contribute to the fatigue of these systems.

The main aim of this research is to evaluate the effect of insertion and disinsertion of dentures on the retentive force of two attachments and their respective connection systems in a mandibular implant-supported overdenture.

## Methods

The attachment systems evaluated in this study were Dalbo-Ball BTI® (Biotechnology Institute S.L., Vitoria, Spain) and Locator® (Zest Anchors, Inc; Escondido, USA) (Fig. 1).



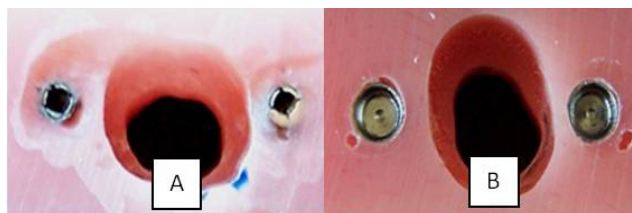
**Fig. 1.** (A) The Dalbo-Ball® system of 3 mm height screwed to the implants in the acrylic block; (B) The Locator® attachment system of 3 mm height (titanium alloy coated with TiN) screwed to the implants in the acrylic block.

In order to measure the retentive force of these attachment systems two acrylic blocks were prepared, which simulated an overdenture retained by two implants.

In one of the blocks (patrix) were incorporated two BTI® implants with external connection and universal platform (BTI Biotechnology Institute S.L., Vitoria, Spain). The implants were placed parallel to each other at a distance of 22 mm, in order to simulate the natural position of the canines. To ensure parallelism between the two implants, surveyor was used. The drill sequence established for the 4.0 platform of the respective implant mark was also used.

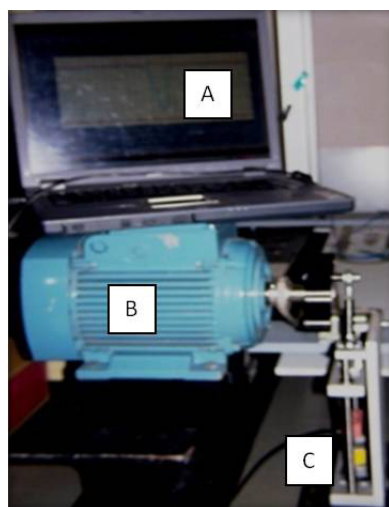
To evaluate each attachment system, the same acrylic block (patrix) was used. These systems, both with a height of 3 mm, were screwed to the implants.

In addition, two different acrylic blocks (two matrix) were set up, into each of which were placed the female of the attachment system, in a position coinciding with the implants of the patrix block. In the Dalbo-Ball® system, capsules mounted in the acrylic block were used. For the Locator® attachment two female systems were tested (clear nylon and pink nylon), each with different retentive capacities, which were inserted into the titanium implant coverings (Fig. 2).



**Fig. 2.** (A) The female capsules from the Dalbo-Ball® system. (B) Titanium covers for the Locator® system, in which the female systems, in clear or pink nylon, are inserted.

To evaluate the retention strength of the attachment systems over time, it was necessary to design a machine with specific equipment for this purpose, which was constructed at the Laboratory of Optics and Experimental Mechanics at the Faculty of Engineering, University of Porto. The main



**Fig. 3.** Complete system designed to measure forces:

(A) Portable computer; (B) Motor; (C) Support for the acrylic blocks linked to the load cell.



**Fig. 4.** Load cell Futek S shape, model Futek® LSB 300,

with a maximum load capacity up to 50 lbs (23 kg) which evaluates forces of tension and compression. Acrylic blocks connected to the system for cyclical fatigue measurement.

constituents of the device constructed were a motor with electronic speed control, a load cell (Futek® LSB 300, with S configuration – Advanced Sensor Technology, Inc. Irvine, California, USA) and a USB Futek® system connected to a computer (Fig. 3). The two acrylic blocks, one with implants (jaw simulator) and the other one with the respective connection system (denture simulator) were coupled to this measurement system (Fig. 4).

Considering that a complete cycle corresponds to an insertion and its respective disinsertion, the number of cycles by time period was calculated taking into account the fact that the patient removes the denture on average three times per day. We evaluated the retention force at 0 cycles (initial force), at 540 cycles (6 months), at 1080 cycles (1 year), at 2160 cycles (2 years), at 3240 cycles (3 years), at 4320 cycles (4 years) and at 5400 cycles (5 years).

The mean values calculated from the statistical tests performed, were obtained by extrapolation of the data supplied by fatigue tests from the USB Futek® system. Thus, the mean force (N) was calculated as well as the standard deviation of each fatigue test (insertion and disinsertion). The speed of insertion/disinsertion was 0.5 Hz, applied constantly over time.

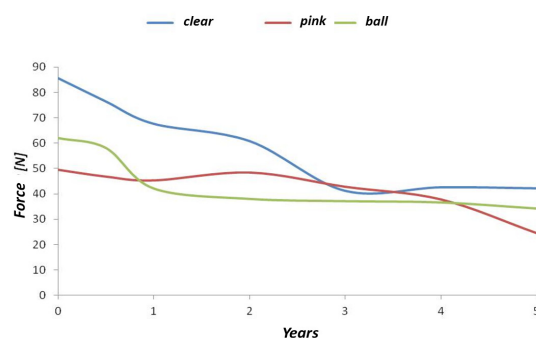
## Results

Table 1 and Figure 5 show the behavior of strength (N) of the three connection systems over time. It can be seen that the Locator® with clear nylon showed the highest initial retention (85.7 N or approximately 8.57 kg), followed by the Dalbo-Ball® system (62.1 N or 6.21 kg) and finally the pink nylon Locator® system (49.6 N or 4.96 kg).

After five years, the mean force exerted was also higher for the clear nylon Locator® system (42.3 N or 4.23 kg), followed by Dalbo-Ball® (34.3 N or 3.43 kg), and finally, the pink nylon Locator® (24.6 N or 2.46 kg).

**Table1.** Mean and standard deviation (SD) values of retention force (N) as a function of time and number of cycles for the three connection systems.

Time (cycles)	Dalbo-Ball		Clear Nylon Locator		Pink Nylon Locator	
	Mean	SD	Mean	SD	Mean	SD
Initial force (0)	62.1	±2.87	85.7	±6.96	49.6	±1.57
6 months (540 cycles)	58.2	±2.04	76.5	±2.42	46.9	±1.71
1 year (1080 cycles)	42.2	±0.58	67.7	±2.68	45.4	±2.02
2 years (2160 cycles)	38.1	±0.62	60.9	±3.79	48.5	±1.95
3 years (3240 cycles)	37.2	±0.59	41.3	±1.57	42.9	±1.25
4 years (4320 cycles)	36.7	±0.65	42.7	±1.83	37.9	±2.06
5 years (5400 cycles)	34.3	±0.47	42.3	±0.77	24.6	±2.30



**Fig. 5.** Evolution of the mean value of the retention forces (N) of the three connection systems used in the tests.

## Discussion

In the literature at present there are few articles reporting the characteristics of wear and retentive strength of attachment systems for overdentures retained by two implants [2,4,6,8,10,14-16]. Because of the variability of the methodology used, there is a wide range of values for the retentive forces of the different types of attachment systems currently available [2,4,6,8,10,14-16]. This variability makes it difficult to validate any comparisons of the retention obtained with these systems and their behavior under simulated use.

Thus, while a specific machine was designed for our study, in the majority of studies [1,3,12,14-23] tests are performed using a universal testing machine: MTS® (MTS SystemCorp, Eden Prairie, MN) and Instron® (Instron Canad Inc., Burlington, ON, Canada).

A common observation in our study and others is the loss of retentive strength which arises under simulated function over time as an inevitable consequence for most attachment systems [16]. One of the main factors of retention loss is the change induced on the components of attachment systems as a result of wear [14,21].

Regarding wear under *in vitro* conditions, there are several underlying factors that influence the retention forces of attachment systems and their characteristics, such as the angle of the implants, the inter-implant distance and the direction of displacement forces applied, as well as the speed of displacement [14,21].

Since the inter-implant distance used in this study was 22 mm, it is worth noting that, according to several authors, inter-implant distance is a factor influencing the retentive strength of attachments [16,21]. On the other hand, Doukas et al. [21], state that there are no standardized rules for the ideal distance between attachments to achieve optimum retention.

However, other factors are shown to exert their influence on the performance of retentive forces in attachment systems, such as the material, design, size and retention type of the system in question [16].

The factors associated with the clinical wear of attachments, including masticatory forces [24,25], parafunctions, and the composition and temperature of saliva, pose limitations on the studies, because they are difficult to simulate *in vitro* [24]. Furthermore, products used for the hygiene of dentures as well as the presence of food residues may also contribute to change in clinical wear [24].

In our study, the retention of the attachment systems tested was evaluated before, during and until reaching 5400 cycles of simulated insertion and disinsertion, this number corresponding to five years of use, if the prosthesis is considered to be removed three times a day.

A decrease in retention at the end of five years was observed for all systems, albeit with different values. This decrease was expected since the friction incurred during insertion/disinsertion causes wear to occur between the base and attachment [24].

However, according to Setz et al. [12], there may also be an increase in retention, since the plastic deformation of the components results in an increase in hardness and surface roughness, improving retention. The deformation of the plastic components, nylon or silicon, is also observable during the fatigue tests, increasing the retention force [25]. This increase may occur due to thermal expansion of the materials during the test [25].

In our study, increased retention is perceptible in the pink nylon Locator® system by the end of two years, or 2160 cycles, when the mean retention force value has increased from 45.4 N to 48.5 N. Between the third and fourth consecutive years or between 3240 and 4320 cycles for the clear nylon Locator® system retentive force rises from 41.3 N to 42.7 N.

It was also observed that for the Locator® and Dalbo-Ball® systems, retention values decrease over time. The force exerted at the end of six months for the clear nylon Locator® system is  $76.5 \pm 2.42$  N, these values dropping to  $42.3 \pm 0.77$  N after five years (5400 cycles). For the Dalbo-Ball® system the values are significantly lower (at the end of six months the force exerted is  $58.2 \pm 2.04$  N and at the end of five years it is  $34.3 \pm 0.47$  N), but higher than the pink nylon Locator® system ( $46.9 \pm 1.7$  N and  $24.6 \pm 2.30$  N).

The evaluation of the wear of attachment systems both in this and other studies [6,12,15,17,22-24] is relatively simple when compared with studies carried out under intraoral conditions, since the forces are applied according to predetermined criteria of insertion and disinsertion. Under clinical conditions, the forces exerted on the attachments are more complex, with tridimensional forces often occurring [12].

The present study evaluated retention after fatigue testing *in vitro*. However, clinically, the retention force may decrease or increase more rapidly, compared with the results presented. Thus, further studies should be conducted to observe the *in vivo* behavior of attachment systems.

## Conclusions

Within the limitations of this experimental study, it is concluded that retentive strength values for clear nylon Locator® attachments, pink nylon Locator® attachments and Dalbo-Ball® attachments decrease over time. It is important to emphasize the need for *in vivo* studies, adapted to clinical reality, which should consider, among other factors, bite forces with different points of application, the presence of saliva and the patient's oral temperature.

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